

Estimating value in service systems: A case study of a repair service system

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The economic structure of service systems has steadily increased in complexity in recent years. This is due not only to specialization in direct material production and services offered, but also in the ownership and management of resources, the role of intangible assets such as process knowledge, and the context in which goods and services are consumed. This increase in complexity represents both a challenge and an opportunity in a service-oriented economy. In this paper, we offer a descriptive structure for the analysis of this complexity which combines graph theory and network flows with economic tools. Our analysis is based on publicly observable information and can be used to analyze service systems in terms of the value they deliver, how they deliver it, and how value can be discovered and increased. We show how this analysis can be applied (in the example of a car manufacturer and its service system for suppliers and dealerships) to improve customer satisfaction and provide options and analysis models for outsourcing decision makers.

INTRODUCTION

Globalization of the world economy has led to an increased ability of companies to outsource the planning, design, manufacturing, and distribution functions of their products and services around the globe. The complexity created by rapid technological advances and the complexity of product design and manufacture have led to the modularization of corporate functions in a wide range of industries (e.g., electronics, car manufacturing, aerospace, and retail).¹ Modularization allows standardization and markets for services providing those standardized functions, and is thus one of the leading causes for the predominance of the service sector in the world economy.² Competitive markets evolve

best-of-breed functions, which in turn encourage deconstruction of formerly vertically organized companies and industries into service systems, also referred to as *value networks*, to capitalize on this advantage. Value networks (and systems) are complex sets of social and technical resources which work together to create economic value.

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Several studies have focused on creating or reconfiguring service value systems.³⁻⁹ The seminal work by Allee defined the ValueNet Works** analysis, using the intuitive HoloMapping** method, a methodology for analyzing the dynamics of value in value networks at the operational, tactical, and strategic levels. Allee's emphasis was on visualization and qualitative methods. In Reference 10, the authors present an e-business modeling approach that combines information technology (IT) systems analysis with economic-based business modeling. They focus on building an e-business model that specifies relationships and e-business scenarios rather than on defining value.

There is a growing need for quantitative methods in the analysis of service systems. Newly deconstructed functions must be priced to generate return through market mechanisms and the deconstructed price structures should merge into the final cost and value delivered through the service system. To improve business processes inside a value network and increase value or other key performance indicators (KPIs), alternative designs for business restructuring or business alliance formations may have to be evaluated. Dependencies among participants also influence value.

In Reference 11, the authors approach the problem of modeling value in service systems by defining an analytical framework. The general problem statement comes from real-life scenarios such as the automotive and electronics value chains, where approaches for optimizing value, cost, and information flows are open and have not been studied to date.

Our approach is to build a flow model for offerings and revenues, with economic entities (roughly equivalent to "business units," or units for which accounting books are kept) as nodes. An economic unit is the basic unit of value creation, and this unit may be a sub-service system by itself. Offerings and revenues are the *material* that flows through arcs between economic entities. Offerings may be goods or services, or a combination of both, and revenues are usually sums of money, although not necessarily, as in the case of a bartering exchange. Our definition of *offering* generalizes the definition given by Normann and Ramirez.⁹ Service systems are statically described by the node and arc graph. Therefore, their analysis has to also take into

account the correlations among the offerings of the partners of a service value network. For example, to repair a car, labor services of technicians have to be combined with new parts provisioning.

Network formation by (economic) agents has been studied in the literature.¹²⁻¹⁴ The objective of this research is the formation of both effective and stable networks, which in general is difficult to achieve. The definition of value used in References 12 and 13, namely the benefits of an agent accrued by his participation in the network minus any costs involved in setting up the network links directly or indirectly, is close to our value definition, as shown in the section "Computing value." However, we focus on a different aspect of network operation in this paper, namely that of network value evolution over time for existing service network systems.

In Reference 11, we make two significant assertions about our model. First, all business interactions can be represented as a set of offerings and revenues. Second, offerings may be or may not be associated with revenues, depending on whether a specific offering is provided for a payment or for free. For example, mail-order houses routinely transfer valuable information, such as what is on sale this week, in the form of a paper catalog or Web site to prospective customers. This transfer does not generate any revenue, though it affects customers' satisfaction. Similarly, not all financial transactions are clearly correlated with transfers. For example, donations to nonprofit economic entities are explicitly required to preclude exchange.

Our model is used to analyze and compute values, taking into consideration partners' satisfaction and the additional value that is created by the relationships that the various partners develop.

In this paper, we apply our e-business model to the repair service system as part of the automotive industry. Dealers, manufacturers, and their suppliers collaborate in order to satisfy customer requests. The manufacturer generates parts catalogs that are delivered to the dealers and suppliers every month.¹⁵ We define business models and compute the value created by the various partners. To increase the value of the repair service system, we propose a transformation of the traditional service system to a new one in which a central portal

created by the manufacturer or an outsourcer provides up-to-date information (the content of catalogs) that can be accessed by any partner. Under these conditions, repair time is reduced and customer satisfaction is increased, leading to increased sales. Additionally, we show that the costs of creating the information system or paying an outsourcer to provide it are lower than the catalog generation and delivery costs. Thus, the total value of the business is increased.

The remainder of the paper is organized as follows. In the sections “E-business model” and “Computing value,” we describe the model and the basic properties of the service system as proposed in Reference 11. In the section “Case study: A repair service system,” we describe the traditional repair service system and compute the value of the various participants. In the section “Transforming the repair service system: The second model,” we propose a transformation of the repair service system, and a variation in “Outsourcers as providers of interoperability: The third model.” In the section that follows, we provide some numerical results. Finally, we provide some concluding remarks and discuss directions for future work.

E-BUSINESS MODEL

In this section, we describe our e-business model, including its formal structure and the role of trust, risk, and transaction and production costs in our value calculations.

Formal model structure

The structure adopted here is the flow graph which comprises two domains: nodes $\mathbf{B} \triangleq \{b_i\}$ taken to be economic entities (businesses units) and transfer objects $\mathbf{O} \triangleq \{o_k\}$ taken to be offerings. For more details on the structure, see Reference 11.

The domains $\mathbf{B}$ and $\mathbf{O}$ are finite sets where the nodes b_i are distinguishable individuals and the objects o_k are classes rather than individuals. Functions that relate the b_i with each other, and the b_i with o_k , will be used extensively, so we define an index notation where economic entities are indicated as subscripts and offerings as superscripts:

$$f_{ij}^k \triangleq f(b_i, b_j, o_k). \quad (1)$$

The static structure of our model is defined by several predicates linking offerings and economic

entities. The binary quantity of a transfer from b_i to b_j , a binary quantity, is indicated by $t_{ij} \triangleq t(b_i, b_j)$.

Note that transfer is directed, so a reverse transfer is not implied: $t_{ij} \not\rightarrow t_{ji}$. If a specific offering o_k can be transferred from b_i to b_j then $t_{ij}^k \triangleq t(b_i, b_j, o_k)$ is true.

The primary characteristic of the b_i for our purposes is that they consume a set of offerings $\mathbf{O}^{in} \subseteq \mathbf{O}$ and produce a set of offerings $\mathbf{O}^{out} \subseteq \mathbf{O}$. For simplicity, we take $\mathbf{O}^{in}$ and $\mathbf{O}^{out}$ to be well defined for each b_i at any point in time. Two special types of b_i are readily identified from these definitions, an *end customer* and an *original producer*. An end customer is defined as a node with zero output—that is,

$$\mathbf{Customers} \triangleq \{b_i : \mathbf{O}_i^{out} = \emptyset, b_i \in \mathbf{B}\}. \quad (2)$$

An *original producer* is defined as a node with no input—that is, a partner who produces the raw materials for the service system:

$$\mathbf{Raw} \triangleq \{b_i : \mathbf{O}_i^{in} = \emptyset, b_i \in \mathbf{B}\}. \quad (3)$$

Additionally, we define the set of sellers to the customers:

Sellers

$$\triangleq \{b_i : (b_j \in \mathbf{Customers}) \wedge (t_{ij}^k \in \mathbf{X}) \wedge (o_k \in \mathbf{O}_i^{out})\} \quad (4)$$

where $\mathbf{X}$ is the set of all t_{ij}^k .

Dynamic analysis depends on the flow rates of offerings and revenue as they change in time. Time is of obvious importance when estimating the value of a service system: value in general can be expected to change with time, since flows change with time. We want to achieve two objectives in this context: first, to capture the variability of the various flows by defining time units that are small enough (e.g., days or weeks) so that variations in flows and values can be exhibited as time progresses from time unit to time unit. We also want to use time periods that are long enough (e.g., quarters or years) so that meaningful and practical value estimates can be made over these longer periods. These time periods will be delimited in our discussion with time instants $T_1, T_2, \dots, T_{N-1}, T_N$.

Transfer relationships between businesses are characterized by the rate of transactions. Since the cost of the goods or services is not visible in a transaction, we will assume that the two relevant properties are quantities of offerings n_{ij}^k (units/time)

flowing in the direction of the link and revenues $R(t_{ij}^k)$ (units/time) flowing in the opposite direction. We also consider the total revenues of b_i from a specific partner b_j to be $R(t_{ij})$. In the simple case, the revenues are related to the quantity by the unit price of p_{ij}^k . All functions and predicates are implicitly assumed to be continuous functions of time. A particularly interesting example occurs if $R(t_{ij}^k) = 0$, i.e., o_k is being given away. This corresponds to the intangible asset transfers referred to by Allee.¹⁶

Intangible assets play a significant role in the creation of value in service systems. Intangible exchanges having no physical structure do not directly generate revenues but influence properties of entities such as the satisfaction index, and help create relationships within a system which affect its evolution. Process knowledge, planning knowledge, technical knowledge, and brand names are examples of intangible assets. Each of these assets could be modeled in our methodology: process and planning knowledge could be modeled by estimating the labor required to achieve that knowledge, and the same applies for the technical knowledge. Brand names can be incorporated in the calculation of the satisfaction index, as explained in a later section.

Offerings of particular interest

The trust that each partner has toward the other can be built on the past experience of the two partners. Contract compliance can be monitored and, at least for new partners, their trust with respect to one another may be affected by third-party reputation and recommendation systems. Quantifying trust is not easy, although there are various approaches in the literature.¹⁷⁻²⁰ A simple approach proposed in Reference 17 is to define relationship levels, i.e., numbers that reflect the overall relationship quality. Increasing relationship levels enhance trust between buyers and sellers.

Closely related to trust is the risk involved when partner b_i transacts business with partner b_j . The risk level is high when the relationship level between two partners is low and is reduced as the relationship level improves. The risk function can best be thought of as insurance that partner b_j is taking against possible future unreliable behavior of partner b_i . In order to simplify our model, we

assume that the property of trust (or equivalently of risk) is represented as an insurance offering. Associating trust with an offering makes the derivation of various properties of our model, such as value computation, simpler because the characteristics that affect entities' strategies are handled in a unified way.

Another set of properties associated with the business operations of a service system partner includes a relationship cost and a transaction cost. The relationship cost function associated with maintaining a certain relationship level is borne by a partner who wants to make his adjacent partners his customers: this may involve promotion campaigns, a free service, gifts, or visits. Each one of these can be modeled as an offering of the supplier to its customer. Obviously, to maintain a high level of relationship (that is expected to generate more revenue), more effort is required at a higher cost. Therefore, a lower customer satisfaction index value during the previous time period will make the cost of the relationship higher in the current period.

There are costs incurred by transactions, such as search and information costs, bargaining costs, and contract monitoring costs.²¹ Again, each one of these activities can be modeled through an offering and an associated revenue; for example, a mediating company may offer its services to buyers to find the best suppliers for the goods or services they seek. A higher satisfaction index with a partner usually signifies a lower cost of tracking transactions with them, thereby lowering the transaction costs.

Finally, there are the production costs, such as labor and investments in buildings and equipment, that are included in our model as offerings between economic entities or between entities and individuals. For example, a construction company may offer a building construction service, a building maintenance company may offer a building maintenance service, and employees may offer their labor as service and are paid salaries as compensation.

Computing value

Each partner cooperates with the others in order for the service system to sell goods and services. It is assumed that each partner sees value in participating in the service system as opposed to not participating, or participating in another service

system. It is important to have a quantitative estimate of this value and to be able to estimate how this value changes with time and with planned or realized changes in the business processes in which a partner participates. In the following, we show how these quantities can be estimated and monitored.

Each partner b_i produces the goods and services indicated in its output set O_i^{out} , in quantities n_{ij}^k , of offering o_k flowing to all partners b_j of the output set. At the end of time interval $[T_{N-1}, T_N]$, partner b_i has revenue based on the following equation:

$$\begin{aligned} R_i(T_N) &= \int_{T_{N-1}}^{T_N} \sum_{t_{ij} \in X} \left(\sum_{k \in O_i^{out}} R(t_{ij}^k) \right) d\tau \\ &= \sum_{t_{ij} \in X} \left(\sum_{k \in O_i^{out}} \int_{T_{N-1}}^{T_N} R(t_{ij}^k) d\tau \right) \\ &= \sum_{t_{ij} \in X} \left(\sum_{k \in O_i^{out}} \int_{T_{N-1}}^{T_N} p_{ij}^k(\tau) n_{ij}^k d\tau \right). \end{aligned} \quad (5)$$

In Equation 5 we assume that service requests are charged individually. If this is not the case, then the corresponding terms of the revenue equation can be replaced by a single constant term representing the flat fee charged for these services.

On the other hand, partner b_i has to purchase the goods and services that he uses in order to produce his own goods and services. Therefore at the end of time interval $[T_{N-1}, T_N]$, the amount spent on purchases is:

$$\begin{aligned} P_i(T_N) &= \int_{T_{N-1}}^{T_N} \sum_{t_{ji} \in X} \sum_{k \in O_i^{in}} P(t_{ji}^k) d\tau \\ &= \sum_{t_{ji} \in X} \sum_{k \in O_i^{in}} \int_{T_{N-1}}^{T_N} p_{ji}^k(\tau) n_{ji}^k d\tau. \end{aligned} \quad (6)$$

Additional value is accrued by the relationship levels that the various partners develop when they sell goods and services to other partners or to the customers. This value is related to the intangible assets concept. A quantified estimate of this value may be the amount of revenue that a particular partner b_i expects to generate by selling goods and services to partner b_j . One way to estimate this

expectation is to look at revenues generated thus far by selling to partner b_j but emphasize the recent past more than the remote past. Letting $\bar{R}_{ij}(T_N)$ be the revenues partner b_i expects to receive from partner b_j in $[T_N, T_{N+1}]$, this expectation can be written as:

$$\bar{R}_{ij}(T_N) = \alpha_i \int_{T_{N-1}}^{T_N} R(t_{ij}) d\tau + \beta_i \bar{R}_{ij}(T_{N-1}) \quad (7)$$

where α_i and β_i are the weights that specify how significant are past data in the estimation of expected revenues, with $0 \leq \alpha_i, \beta_i \leq 1$, and $\alpha_i + \beta_i = 1$.

A better way to gauge the relationship value is to include a satisfaction index, since it is intuitively reasonable that a declining satisfaction index should lower revenue expectations and therefore the value of a relationship, while an increasing satisfaction index should raise revenue expectations and therefore the relationship value. The satisfaction index is a rational preference relation intrinsic to an entity that is related to prices, service or product delivery time, brand names, product quality, and other factors. We assume that each entity acting as a customer to another entity knows its own satisfaction index. We also assume that through market research, questionnaires to their customers, and other means, the suppliers also have knowledge of their customers' satisfaction indices. Letting $Sat_{ij}(\tau)$, be the satisfaction of partner b_j being a customer of partner b_i at time τ , the ratio:

$$\delta Sat_{ij}(T_N) = \frac{(Sat_{ij}(T_N) - Sat_{ij}(T_{N-1}))}{Sat_{ij}(T_{N-1})} \quad (8)$$

provides an estimate of the percentage of increase or decrease in expected revenues of partner b_i from partner b_j during the time from T_{N-1} to T_N . These differences, however, may only be measuring temporary oscillations of satisfaction. It is thus better to measure longer-term trends that can be estimated by computing the weighted averages of the satisfaction index:

$$\overline{Sat}_{ij}(T_N) = \gamma_i Sat_{ij}(T_N) + \delta_i \overline{Sat}_{ij}(T_{N-1}) \quad (9)$$

where $0 \leq \gamma_i, \delta_i \leq 1$, and $\gamma_i + \delta_i = 1$. For more details on deterministic prediction models based on weighted averages, see Reference 22.

The satisfaction index is a concept which is very close to the "relationship level" defined in Reference 6. We can now define an estimate of the expected

value of the relationship between partners b_i and b_j in $[T_N, T_{N+1}]$ as:

$$\begin{aligned} v_{ij}(T_N) &= \overline{R}_{ij}(T_N) + \frac{\overline{Sat}_{ij}(T_N) - \overline{Sat}_{ij}(T_{N-1})}{\overline{Sat}_{ij}(T_{N-1})} \overline{R}_{ij}(T_N) \\ &= \frac{\overline{Sat}_{ij}(T_N)}{\overline{Sat}_{ij}(T_{N-1})} \overline{R}_{ij}(T_N). \end{aligned} \quad (10)$$

The expected value of all the relationships that a partner has “downstream” in the service system (i.e., with all those partners who are the receivers of its offerings) is given by:

$$v_i(T_N) = \sum_{t_{ij} \in X} v_{ij}(T_N). \quad (11)$$

Special care has to be taken for the customers of the service system, since they do not have, by definition, any downstream relationships. The customers generate value to the service system through their willingness to pay. This is usually expressed through a utility function,²³ which depends on the satisfaction index of the customers and on the price p_k of the offerings they buy: $u_i(Sat_i(\tau), p_k(\tau))$. We can now express the relationship value for any partner as:

$$v_i(T_N) \triangleq \begin{cases} \sum_{t_{ij} \in X} v_{ij}(T_N), & b_i \in (\mathbf{B} - \text{Customers}) \\ u_i(Sat_i(T_N), p_k(T_N)), & b_i \in \text{Customers} \end{cases} \quad (12)$$

We may now compute the value that partner b_i gets from participating in the service system, at the end of time interval $[T_{N-1}, T_N]$:

$$\begin{aligned} V_i(T_N) &= \text{profits from interacting with partners in} \\ &\quad [T_{N-1}, T_N] \\ &\quad + \text{expected value with buying partners in} \\ &\quad [T_N, T_{N+1}] \\ &= R_i(T_N) - P_i(T_N) + v_i(T_N) \end{aligned} \quad (13)$$

This value computation is similar to the one used in References 12 and 13, since we are also computing the benefits accrued by a partner’s participation in the service network (revenues from the buying network partners plus relationship value) minus costs paid to the network supplying partners.

An important observation is that if the sum of revenues and values derived from a partner’s relationships with the buying partners is smaller than the sum of costs incurred because of his

participation in the service system, then the partner has a net loss due to his participation, at least up to time T_N . This partner should examine whether there is value in its further participation in the service system. Even if the value is found to be positive, a partner may want to examine whether participating in other service systems, or not participating in service systems at all, would generate a higher value. Another question that a partner may ask is whether, by appropriately lowering the various components of the participation costs and increasing the revenues or his relationships’ value, he may increase the overall value of his participation in the service system.

The value of the whole service system (taking into account that for internal flows of goods and services, revenues and costs cancel themselves out) can be calculated as:

$$V(T_N) \triangleq \sum_{b_i \in \text{Sellers}} R_i(T_N) - \sum_{b_i \in \text{Raw}} P_i(T_N) + \sum_{b_i \in \mathbf{B}} v_i(T_N). \quad (14)$$

If the sum of revenues plus values derived from cooperation in the service system is smaller than the participation costs incurred, then the service system has a questionable future. It is important to note that the time horizon considered for deriving the value of a service system is a parameter that has to be properly set; it must be long enough to compensate for the changes of the dynamic system and short enough to offer the right incentives for updating the participants’ strategies.

CASE STUDY: A REPAIR SERVICE SYSTEM

We apply our model to the example of a car manufacturing value chain. In the following subsections, we describe the business objectives, difficulties, and metrics that are involved in this system.

A conventional repair service system

The conventional service system is described briefly in the following. (For a more extensive description, see Reference 15.) Owners of original-equipment-manufacturer (OEM), brand-name cars arrive for repairs at the dealerships of the OEM. Technicians diagnose the problem to be repaired, order parts, and perform the necessary repairs. However, ordering parts is a complex process, since it involves scrutinizing the failure symptoms, identifying the faulty part, asking for advice from expert techni-

cians available from the OEM (including information about warranty-covered parts, new parts, etc), and then ordering the appropriate (possibly upgraded) replacement parts. Ordering of parts is performed by the dealer's parts manager, who first must access the parts catalog; check local, OEM, and supplier inventories; and eventually submit parts orders. From our experience in working on these and similar problems, it is realistic to assume that the dealers' technicians perform these searches for approximately one hour every day and that about one half hour is wasted by the parts manager in checking parts catalogs and inventories. The parts manager can buy parts either from third-party suppliers (TPSs) or through the OEM, from the certified supply-chain suppliers (SCSs). The repair service and the new parts are paid for by the OEM if service and parts are covered by the warranty or by the car owner if they are not. The OEM offers advice to dealers' technicians for free.

The OEM collects all (new) parts, warranty, and failure symptoms information and uses the services of a content preparation provider to generate new parts catalogs and mail them to its suppliers and dealers every month.

All these delays contribute to longer repair times as perceived by the car owners, thereby lowering their satisfaction. A reduction in the customer satisfaction index is typically an indicator that fewer customers are going to buy the brand-name cars of this OEM, resulting in a negative effect on the overall service system. On the other hand, a rising customer satisfaction index is a good indicator of stronger sales for this brand name. We now examine the repair service system in greater detail.

Value analysis for the repair service system

In *Figure 1*, we show the flows of offerings among the various partners (shown as circles) in the repair service system. Offerings and payment flows are represented by arcs. We represent technicians, the parts manager, and the help desk experts as economic entities, each of which is offering their labor as a service to the service system, instead of lumping these entities as "production cost" of the dealers or the OEM. To keep the example simple, we ignore relationship costs, transaction costs, and risk costs. *Relationship costs* are free offerings of a partner to its customers. *Transaction costs* can be modeled as offerings by dealers and OEM managers

supervising the exchanges of the system; *risk costs* can be modeled as an insurance policy offering. We also ignore other standard operational costs, such as capital equipment and utilities. We measure rates of offerings and payment flows per month and we compute values on a yearly basis. We assume, for simplicity, that these rates remain constant over a period of a few years. In the following subsection, we perform value computations for the various partners.

Business models for dealers: Value computation

In the after-sales market, a dealer makes money by selling parts to replace faulty ones in customers' cars and by charging for the fault diagnosis and labor involved in part replacement. If the service is covered by the warranty, then the OEM pays for it; otherwise, it is the car owner who pays. Therefore, the total cost of a repair is

$$c = l_e \bar{r} + \bar{p} \bar{n} \quad (15)$$

where l_e is the (external) labor rate paid by the car owner, reduced to a per-hour rate, $\bar{r}$ is the mean repair time, $\bar{p}$ is the mean price and $\bar{n}$ is the average number of parts required for each repair. In addition, if s is the rate of service requests arriving at the dealer every month, then, for the dealer, the annual revenues will be:

$$R_d = 12sc. \quad (16)$$

The dealers purchase labor from their technicians at a rate of Nl_T , where N is the number of technicians and l_T is the technicians' labor rate per month. The dealer also purchases labor from the parts manager at a rate of l_{pm} per month.

It is necessary here to adopt a simplified model for the dealer's inventory. We assume some initial purchases for stocking the inventory have already been performed in the past. Based on customers' preferences, the dealer decides which parts are stocked locally. If the desired part is found in the inventory, it is used and immediately reordered. Thus, the parts manager has to work on the order of the part whether or not the part was found in the inventory. If it is not found, then it is ordered either from the TPS or from the OEM. The only difference between a part being found or not is, of course, whether or not the car owner must wait for it to arrive at the local dealer. Waiting negatively affects customer satisfaction.

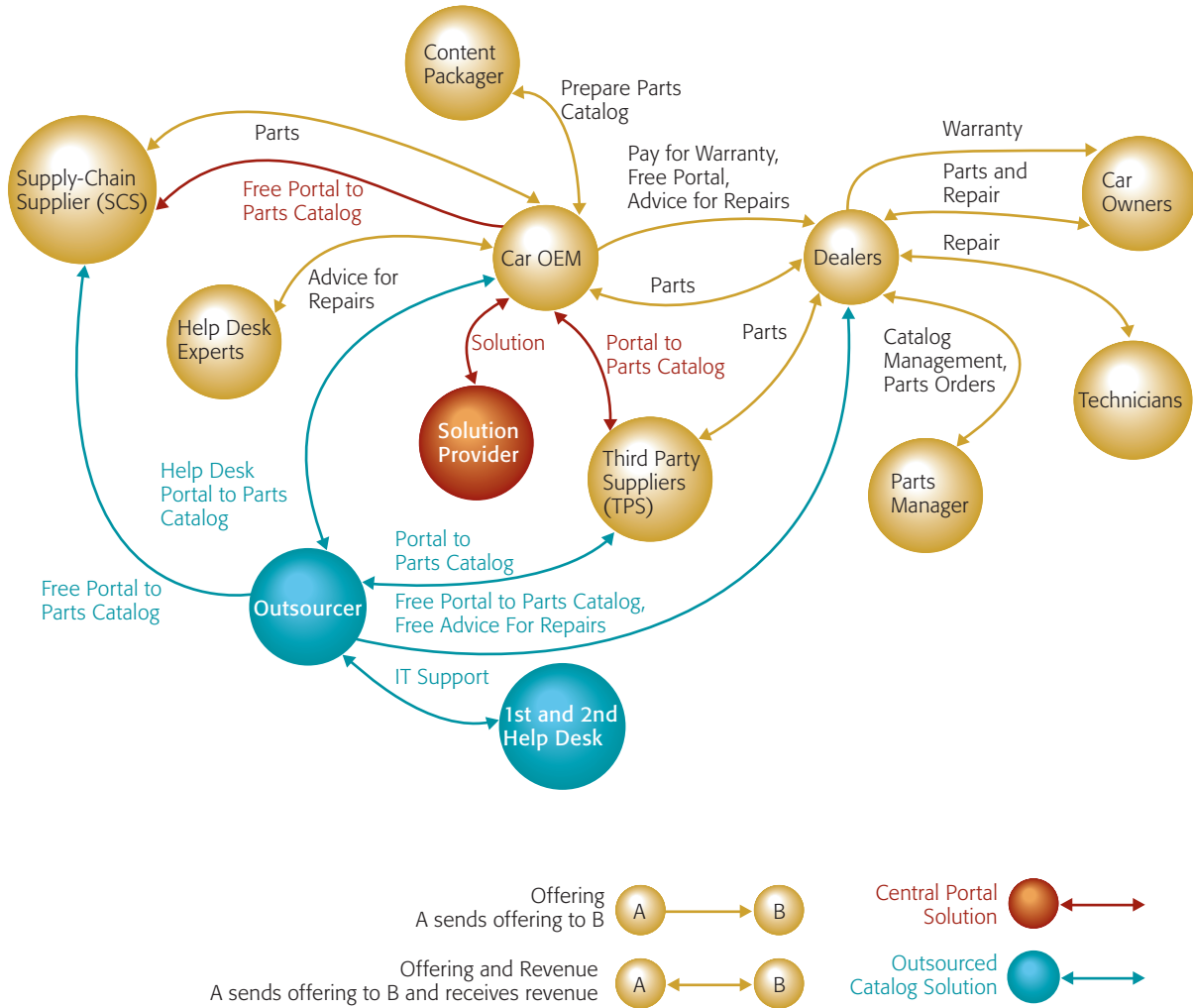


Figure 1
Repair service system

Based on the preceding discussion, the dealer orders $f = s\bar{n}$ parts per month at an average price of $\bar{p}_s$ per part from the TPS and at an average price of $\bar{p}_o$ per part from the OEM. α is the percentage of parts that the dealers buy from the OEM. In addition, the dealer gets advice for the repairs from the help desk experts of the OEM for free. Therefore the dealer's total annual purchases are:

$$P_d = 12(f(\alpha\bar{p}_o + (1 - \alpha)\bar{p}_s) + l_{pm} + Nl_T). \quad (17)$$

A dealer sees value in its relationship with its customers, and this, in the after-sales market, is due to the expectation of future sales of parts and services (essentially fixing car problems or adding new accessories). An estimate of this expectation can be made by looking at past sales and the customer satisfaction index $\overline{Sat}_d(\tau)$ (normalized

between 0 and 1) that may be defined as the sum of terms such as:

- the brand-related component
- the price-of-labor and parts-related component
- the time-of-service-related component (e.g., a decaying exponential), which could be further subdivided into the waiting time until service starts, plus the service time, plus the waiting time for ordered parts
- the component related to the percentage of faulty diagnoses

The value that a dealer gets out of its participation in the service system during year n is:

$$V_d = 12s(l_e\bar{r} + \bar{p}\bar{n}) - P_d + \frac{\overline{Sat}_d(T_n)}{\overline{Sat}_d(T_{n-1})}\bar{R}_d(T_n). \quad (18)$$

The mean repair time $\bar{r}$ is the time to do the technical research, the time for the parts to be ordered by the parts manager, and the time to perform the repair. In a sense, only the time to perform the repair is really useful time, as the other two components are delays introduced because the data on parts and failure symptoms is not readily accessible or may not be up-to-date.

Reducing these delays will, of course, reduce the dealers' revenues (since they charge service time to their customers) but it will also reduce labor costs and increase customer satisfaction, since this will reduce overall repair time and expense. Increased customer satisfaction can be expected to bring in more customers, thereby generating a "virtuous cycle" of increased revenues.

Value computation for the OEM

The OEM offers advice for repairs to the dealers' technicians for free and certified high-quality parts to dealers at a rate of αf per month. Assuming an average price of $\bar{p}_o$ per part, the OEM has revenues of $R_o = \bar{p}_o \alpha f$ per month. The OEM purchases the following offerings:

- Parts from the SCSs at a rate roughly equal to $\alpha f D$, where D is the total number of dealers. We adopt the same simple inventory model as that adopted for the dealers. The OEM pays $\bar{p}_c \alpha f D$ per month, where $\bar{p}_c$ is the average price per part that the SCS charges.
- Warranty repairs and defective parts replacements from the dealers at a rate of $w \alpha f$ per month, for which the OEM pays $w \alpha f c$ per month per dealer, where w is the percentage of defective parts per month.
- Parts catalog content preparation and mailing at a rate of P per month, and mailing at a rate of M per month.
- Help desk experts' labor at three distinct labor rates (l_1, l_2, l_3) per month corresponding to the first-, second-, and third-level (expert-level) help desk support of N_1, N_2 , and N_3 experts.

Let $\overline{Sat}_o(\tau)$ be the satisfaction index measuring the dealers' satisfaction about the parts that they purchase from the OEM at time τ . The satisfaction index depends on the price and the quality of the parts. A lower satisfaction index lowers the expectations for sales of parts by the OEM, signaling that the dealers will shift the purchasing of parts to the

TPSs. The value the OEM receives from the service system during year n is:

$$V_o = 12D(\alpha f(\bar{p}_o - \bar{p}_c) - w \alpha f c - M) - 12P - 12(N_1 l_1 + N_2 l_2 + N_3 l_3) + \frac{\overline{Sat}_o(T_n)}{\overline{Sat}_o(T_{n-1})} \overline{R}_o(T_n). \quad (19)$$

Value computation for the other partners

A TPS makes a single offering to the dealers by selling car parts at a rate of $D(1 - \alpha)f/T$ per month, where T is the number of TPSs. Therefore, the value all of the TPSs are getting from the service system during year n is:

$$V_s = 12D\bar{p}_s(1 - \alpha)f + \frac{\overline{Sat}_s(T_n)}{\overline{Sat}_s(T_{n-1})} \overline{R}_s(T_n). \quad (20)$$

An SCS makes a single offering to the OEM by selling car parts at a rate of $\alpha f/C$ per month, where C is the number of SCSs. Therefore, the value all of the SCSs are getting from the service system during year n is:

$$V_c = 12D\bar{p}_c \alpha f + \frac{\overline{Sat}_c(T_n)}{\overline{Sat}_c(T_{n-1})} \overline{R}_c(T_n). \quad (21)$$

The values of the other partners are computed similarly. The satisfaction indices for the laborers (parts managers, technicians, help desk experts) can be thought of as their performance evaluations by their employers.

Total value of the repair service system

In the expression for the value of the entire repair service system, intra-partner revenues and purchases of offerings cancel each other out and the expression becomes:

$$V = \sum_{b_i \in \{\mathbf{B}-\text{Customers}\}} v_i(T_n) + \sum_{b_i \in \{\mathbf{C}-\text{Customers}\}} u_i - 12Dw \alpha f c \quad (22)$$

The values (v_i) of the partners depend on the revenues of each partner modulated by the ratio of present versus past satisfaction indices. The term $12Dw \alpha f c$ in Equation 22 represents the costs of warranties paid by the OEM.

Transforming the repair service system: The second model

The strategic question for the OEM is what to do in order to increase the value of its service system. There are obviously various ways to accomplish this, as will become apparent from the subsequent

computations; two of them are to increase customer satisfaction, which would eventually lead to more sales, and to cut costs. Another way is to reduce repairs that have to be covered by warranty by improving parts quality. Quality improvement processes are an extensive topic by themselves and will not be addressed here.

The first repair service system transformation that we consider is the one in which a solution provider achieves interoperability between the partners' information systems through a central portal operated by the OEM. The portal allows everyone to have access to up-to-date information about parts at any time, as soon as this information becomes available to the portal. This solution is shown in the red-colored areas of Figure 1. The obvious way to increase value by upgrading the IT infrastructure is to eliminate mailing costs.

We now examine the changes to the values of the partners. The dealer continues to make the same offerings; its value is thus calculated by Equation 18. The repair time is now reduced, because of the time saved by both the parts manager and the technicians in identifying and ordering parts. This decreases revenues (since the labor charged is reduced) but at the same time, the customer satisfaction index goes up in expectation of future increased sales volume. It should be evident that this constitutes a trade-off that could increase or decrease the value of the dealer depending on the parameters involved. This, in turn, will influence the value of the service system.

There are several changes in the value of the OEM:

- The first year the solution is introduced, the OEM pays a relatively high price (C_s) for the solution, an offering of the solution provider. Maintenance is paid out to the solution provider the following years (another offering of the solution provider) at a rate M_s per month.
- The offerings of the content packager are modified, since there is no need for mailings any more, so the OEM has some savings from this.
- The portal is made available as a free offering to the dealers and the SCSs, but access to it is given for a charge to the TPSs at the rate l_a , thus producing some additional revenue.

As can be seen from the preceding, depending on the values of the parameters involved, the OEM can hope to increase its overall value, which is given by:

$$V_o = 12D(\alpha f(\bar{p}_o - \bar{p}_c) - awfc) + 12Tl_a - 12P - 12M_s - 12(N_1l_1 + N_2l_2 + N_3l_3) - C_sI_{(n=1)} + \frac{\bar{Sat}_o(T_n)}{\bar{Sat}_o(T_{n-1})}\bar{R}_o(T_n) \quad (23)$$

where $I_{(n=1)}$ takes the value 1 if year $n = 1$, or 0 otherwise.

The parts manager and the technicians may see their involvement-per-part-ordered decrease, since they can more easily identify and order new parts, but because of this some of them may be characterized as redundant and therefore lose their jobs. However, if the customers increase, there will eventually be more work for them. Similar observations apply for the help desk experts.

The TPSs will see an increase in their expenses (because they have to pay for access to the portal of the OEM), which they may try to pass on in the prices of their parts, although this is probably unlikely, given the sensitivity of the car owners to price hikes. It is more likely that they will try to convert to SCSs.

Finally, the content packager will lose some if its revenue because the parts catalog mailings will be stopped.

Outsourcers as providers of interoperability: The third model

The second repair service system transformation that we propose is a variation of the previous solution, in which the solution provider is replaced by an outsourcer who provides the electronic catalog system and its maintenance as a service. This solution is shown in the blue-colored areas of Figure 1. The only change we observe in the calculation of values concerns the relationship between the OEM and the outsourcer:

- The high price for the purchase of the solution and maintenance costs paid by the OEM are eliminated,
- The OEM pays the outsourcer for the offering of the portal as a service, on a yearly basis, and
- The outsourcer undertakes the labor of help desk experts levels 1 and 2.

In comparison to the previous business model, the value of the OEM may increase or decrease in this model, depending on the specific negotiations that

Table 1 Values for calculations for first model

Number of parts ordered per month f	200
Percentage of parts the dealer buys from OEM α	0.8
Mean price per repair $\bar{p}$	\$150
Mean repair time	2 hours
Average OEM price per part $\bar{p}_o$	$0.8 * \bar{p}$
Average TPS price per part $\bar{p}_s$	$0.5 * \bar{p}_o$
Labor rate for parts manager l_{pm}	\$2,000
Number of technicians N	5
Technician's labor rate per month l_T	\$900
Service requests rate per month s	100
Labor rate paid by customer l_e	\$50
Average number of parts per repair $\bar{n}$	2
Parts catalog preparation rate per month P	\$85,000
Number of TPSs T	100
Dealer's satisfaction index for OEM for each n $Sat_d(T_n)$	0.7
Dealer's revenues $R_d(T_n)$	\$480,000
Number of dealers D	10,000
Average SCS price per part $\bar{p}_c$	$0.6 * \bar{p}_o$
Percentage of services that are in warranty w	0.1
Parts catalog mailing rate per month M	10
First-level employees labor cost $N_1 l_1$	$100 * 600$
Second-level employees labor cost $N_2 l_2$	$30 * 1000$
Third-level employees labor cost $N_3 l_3$	$10 * 1500$
OEM's satisfaction index for dealers for each n $Sat_o(T_n)$	0.7
Revenues of OEM $R_o(T_n)$	\$921,600,000

take place between the OEM and the solution provider or the outsourcer, respectively.

RESULTS

In this section, we apply the previous business models using reasonable values (given in **Table 1** through **Table 3**) and present the results. We use the same values for the parameters in the three models,

Table 2 Values for calculations for second model (shows differences in comparison to the first model)

Mean repair time $\bar{r}$	1.5 hours
Number of first-level employees N_1	80
Number of second-level employees N_2	25
Number of third-level employees N_3	5
Access rate a TPS is charged l_a	\$5,000
Total cost of purchasing the solution C_s	\$1,000,000
Annual cost of maintaining the solution M_s	\$10,000

except for the mean repair time and the number of personnel in the help desk, which are reduced in the second and third models. This is due to the reduced time required by partners to access information. Note that number of first- and second-level help desk employees is further reduced in the third model because of their increased expertise.

We observe that the dealer's value decreases, from the first model to the second and third models, from \$462,240 to \$402,240 due to the decrease in repair time, which causes customers to pay less for each repair, reducing the revenues of dealers as well. Concerning the value of OEM, in the first ("as-is") model it is \$2.02122 billion and in the second and third, it is \$2.07726 billion and \$2.0797 billion, respectively. These calculations are explained by the reduced cost for the OEM to provide the catalog to dealers, the reduced number of employees needed for each level of the help desk, and the increase in revenues due to the access fees from TPSs. In the third model, we have a further increase because the

Table 3 Values for calculations for third model (shows differences in comparison to the first model)

Mean repair time $\bar{r}$	1.5 hours
Number of first-level employees N_1	20
Number of second-level employees N_2	10
Number of third-level employees N_3	5
Access rate a TPS is charged l_a	\$5,000
Annual rate for purchasing the service of solution C_s	\$500,000

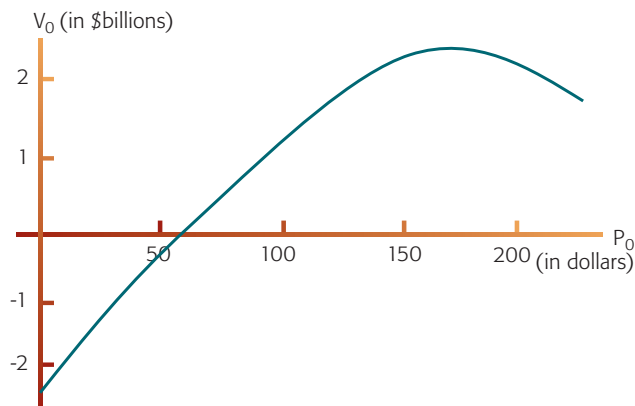


Figure 2
OEM value as a function of price (for first model)

first and second levels of the help desk have been assigned to the outsourcer. Additionally, the value of the TPSs decreases from \$0.6528 billion to \$0.6468 billion due to the additional cost that the third-party suppliers (TPSs) are paying to the OEM for access to the electronic catalog. The value of the SCS remains the same (\$4.70016 billion) in all models. These changes affect the total value of the service system, which decreases from \$18.8447 billion to \$18.5931 billion in the second model and to \$18.5915 billion in the third model. This is reasonable, since the decrease of dealers' value is higher than the increase of the other partners' value. The difference in results between the second solution and third solution is caused by the fact that the revenues of the solution provider in the second model are higher than the revenues of the outsourcer of the third model.

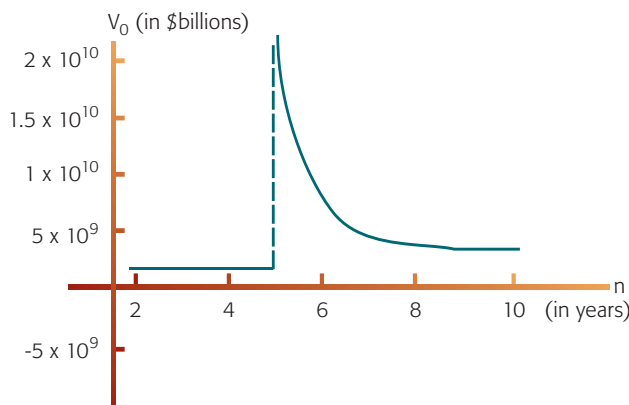


Figure 3
OEM value as a function of time

For the calculations, we have assumed one type of customer, each having utility function $u(p) = 3p$. The conclusion from these calculations is that there are conflicting interests between partners when the electronic catalog is introduced.

It is interesting to examine what happens if we increase the rate of service requests arriving at the dealer every month in addition to the decrease of the repair time in the second and third models. With this change, we take into consideration that the reduced repair time causes more customers to buy cars produced by the OEM, so more repairs arrive at the dealers. In this case, the value of the dealer increases from \$462,240 to \$753,360 in the second and third models. The other values of the partners increase even more.

We now examine the fluctuations in the OEM value (V_o) with respect to the price ($\bar{p}_o$) in year n . The dealer's satisfaction index depends on $\bar{p}_o$ and is given by $Sat_o(T_n) = 1 - \bar{p}_o^2/40000$. The graph shown in **Figure 2** depicts the function of V_o (in billions). We can see that for low prices, the value is negative, due to costs that are higher than revenues. The value increases up to the price 165, where it is maximized. Then it starts decreasing, because the satisfaction index diminishes at high prices.

Finally, we compare the first and second models from the point of view of the OEM. **Figure 3** shows the value as a function of time (in years). For the first five years, the first model is used; for the next five years, the second model is used. We observe that the value at the year the model is changed increases sharply, due to high expectations for the new model. As years pass, the value decreases, though it finally reaches a higher level than that of the first model.

CONCLUSIONS AND FUTURE WORK

In this paper, we have provided a structure for studying service systems and have defined the various properties and relationships among the participating economic entities. We calculated the total value such service systems generate, taking into account the value accrued due to the transfers of offerings as well as the expected value due to the partners' satisfaction in the various relationships. We applied our model to the car manufacturing

service repair system and proposed a solution to reduce costs and thus increase value.

What is of interest for business processes is the extent to which they contribute to the improvement of the partners' KPIs. To be able to reason about service systems and predict their future behavior relative to critical KPIs (such as revenues, costs, and customer satisfaction index), it is important to understand the mechanisms through which service systems emerge, survive, prosper, and (at a later time) decline and perish.

Related to these considerations, the next step in our analysis would be to provide a framework in order to determine the partners' strategies (including the selection of prices or quantities) such that the total value or each partner's value is optimized. In addition, our prediction models for estimating relationships' value could be extended to stochastic ones. Prediction models should also include other parameters, such as estimators of the general economic situation or of the industry sectors where a value network belongs. Examples of such indicators include the economic leading indicators.

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